FLOODING POTENTIAL AT THE IDAHO CHEMICAL PROCESSING PLANT

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1. INTRODUCTION

1.1 Purpose and Scope

This report resulted from an examination of the flooding potential at the Idaho Chemical Processing Plant (ICPP) area. Geological, hydrological and climate characteristics for the basin were compiled from the literature and unpublished records. The compiled data, together with the results of certain limited investigations, may be used by plant safety personnel to evaluate possible flood situations at the ICPP.

1.2 Prior Work

Streamflow records for the area are limited. Some observations dating back to the last century have been recorded, but stream gauging stations were not operated near the National Reactor Testing Station (NRTS) until the early 1900's. Gauging stations in the nearby mountain basins were relocated from time to time or were operated intermittently; thus, no station provides continuous data over the entire period of record. Within these mountain basins the long-term problem was the lack of water; therefore, the early gauging station locations were located to determine sustained flows of water for irrigation use in the basins. Because of basin characteristics, records for water use in the mountain basins do not give the best information for evaluating flood crests on the Snake River Plain. This will be discussed further in Section 2.

The U. S. Geological Survey (USGS) group, based at the NRTS, has measured the flows of surface water in the Big Lost River channels on the NRTS since the 1950 decade. This work is reported in USGS annual open file reports for the NRTS[2,3,4,5]. Lampke computed stage-discharge curves for the Big Lost River channels and for the NRTS Flood Diversion Facilities channels[6]. Carrigan computed flood volumes and return periods up to 300 years for Big Lost River floods at the NRTS Flood Diversion Facilities. His report indicates that the present facilities will divert floods of up to 55-year return period and can be upgraded to divert 300-year return period floods[7]. Aerojet Nuclear Company (ANC) Construction Engineering Division prepared a proposal and cost estimates for upgrading the NRTS Flood Diversion Facilities; this work is scheduled to be accomplished in FY-75.

A flood study was accomplished for the Power Burst Facility (PBF) area in 1972. Preliminary predicted maximum precipitation (PMP) calculations were made for the Big Lost River Basin and portions of the Snake River Plain; however, flood routing was not done in that study. Comparison of the total volume of rain, from a 72-hour PMP storm with channel storage on the Big Lost River Flood Plain, indicated that there would not be enough water to threaten PBF even if the entire volume of water was routed past PBF in a few hours.

In 1972, R. E. Schindler made some preliminary studies to estimate the effects of a maximum flood in the Big Lost River on ICPP. He made a comparative study using other basins in eastern Idaho where PMP computations and flood routing studies had been made. The computed floods were adjusted to the Big Lost River Basin as a function of basin size. His work indicated a maximum flood crest between 25 thousand and 78 thousand cubic feet per second (cfs) at the outlet of the Big Lost River Basin. He concluded that the Big Lost River flood would be near the low end of the range by comparing the shapes of the other basins to the shape of the Big Lost River Basin (for equal areas, similar soils and equal precipitation, a long, narrow basin will produce a lower flood crest than a round basin).

2. BASIN CHARACTERISTICS

2.1 General Statement

In the literature, the adjacent mountain basins are usually defined as shown on Figure 1. This is because the streams, other than the Big Lost River, seldom flow onto the Snake River Plain. Essentially all the surface water generated in the mountain basins is consumed before the streams cross the lower boundaries shown on Figure 1.

The ICPP area is located near the Big Lost River on the NRTS. Most of the NRTS is in the Pioneer Basin[8], a closed topographic depression on the Snake River Plain. The Pioneer Basin receives intermittent surface flow from the Big Lost River, Little Lost River, and Birch Creek Basins which are located in the mountains to the north.

The Big Lost River Basin and the upper portion of the Pioneer Basin are of primary interest for evaluating ICPP floods. A low divide near Circular Butte (east of Test Area North [TAN]) will allow water to move from the Pioneer Basin to the Mud Lake Basin when water ponds to about 4,800 feet elevation. The combined Mud Lake and Pioneer Basins would drain to the Snake River over a divide near Sage Junction (a few miles further east) before water backed up the Big Lost River to ICPP.

2.2 Geology

The Big Lost River, Little Lost River, and Birch Creek Basins were formed by normal faulting[9] with the valley blocks dropping several thousand feet relative to the

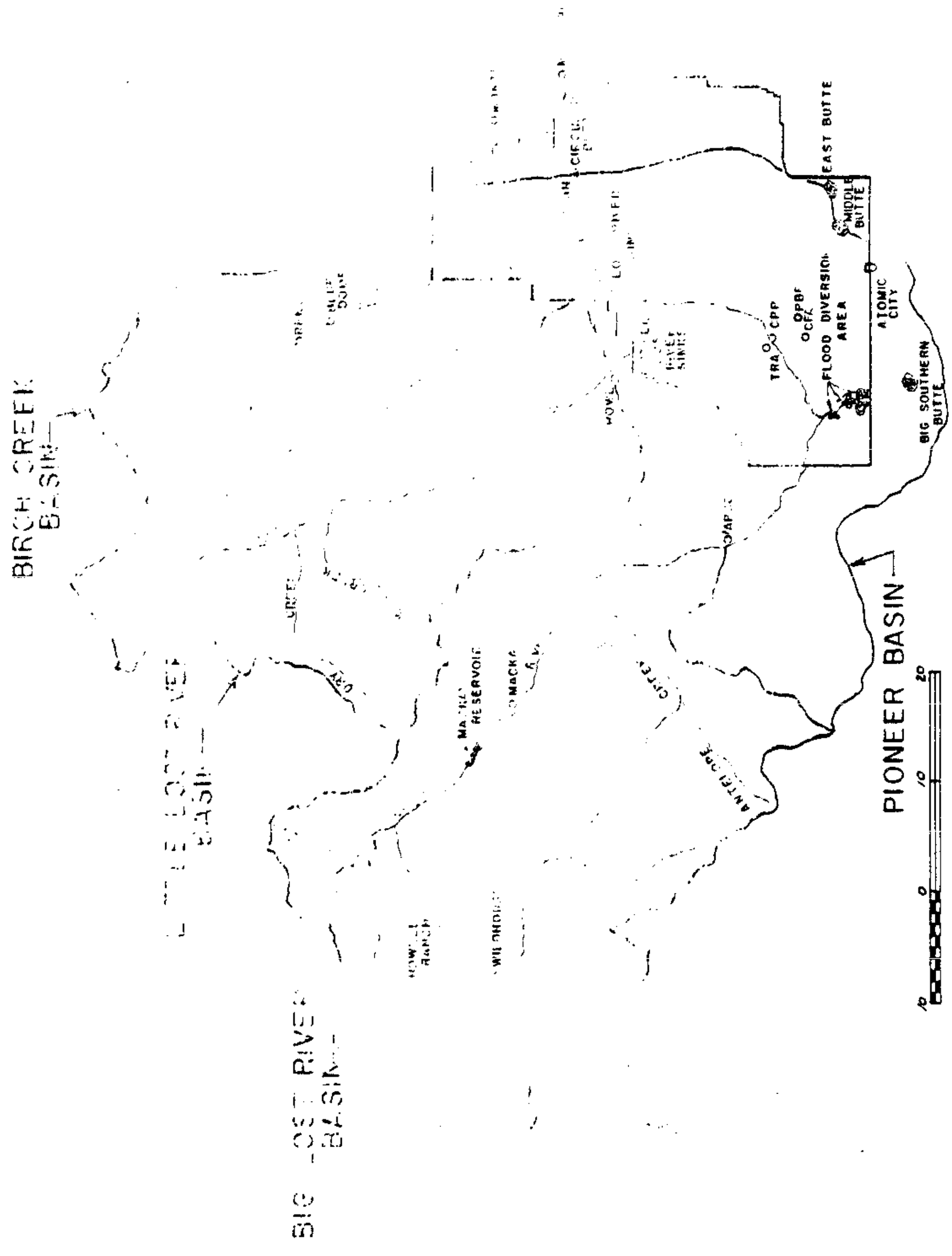


FIGURE 1. [illegible] figure shows the four basins as they have been [illegible] 2. The [illegible] area could be considered to be the Big Lost [illegible] seldom discharge to the plain as an integrated [illegible] For convenience, past writers have considered the basins separately.

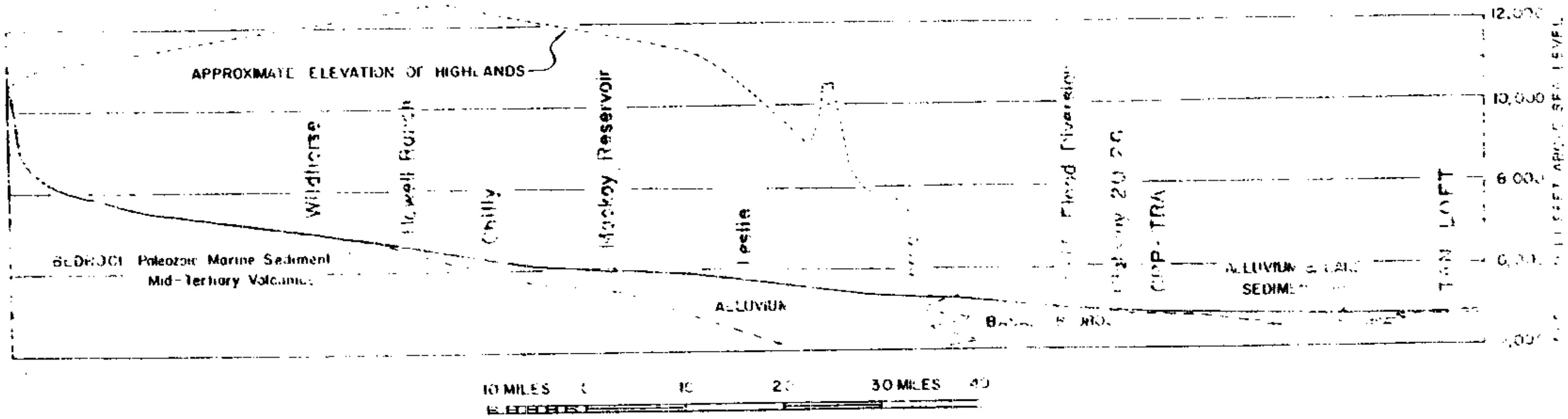
mountain blocks. Subsequently, erosion removed material from the mountain blocks. The eroded material was deposited as alluvial gravel fans at the base of the mountains or was washed downstream to be deposited as alluvium on the lower flood plains of the streams (see Figure 2). Pioneer Basin is located almost entirely on the Snake River Plain. The bedrock here is basalt which is highly permeable due to flow structure, cracks, joints, and lava tubes[10,11]. A portion of the basin is covered with gravel and alluvium deposted where the mountain streams flow onto the plain; however, most of the area consists of basalt either exposed at the surface or covered with a few inches of wind-deposited soil (loess)[8].

The Big Lost River rises in a bedrock basin above Howell Ranch (Figure 2): the main tributary, Antelope Creek, flows for more than two-thirds of its length through a bedrock basin where infiltration is low. Below Howell Ranch, the Big Lost River flows over fan gravels and alluvium where water readily infiltrates.

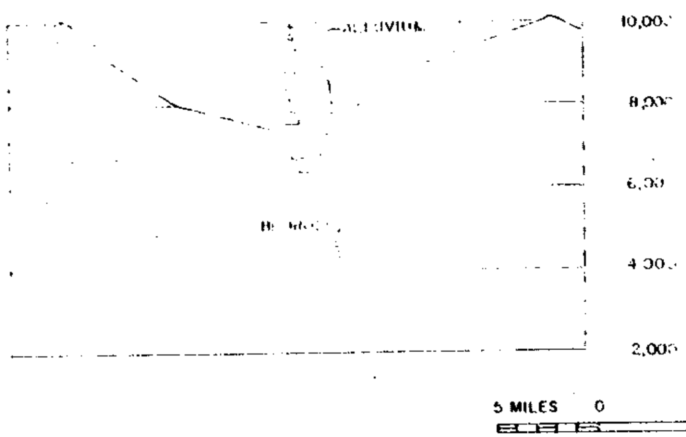
2.3 Climate

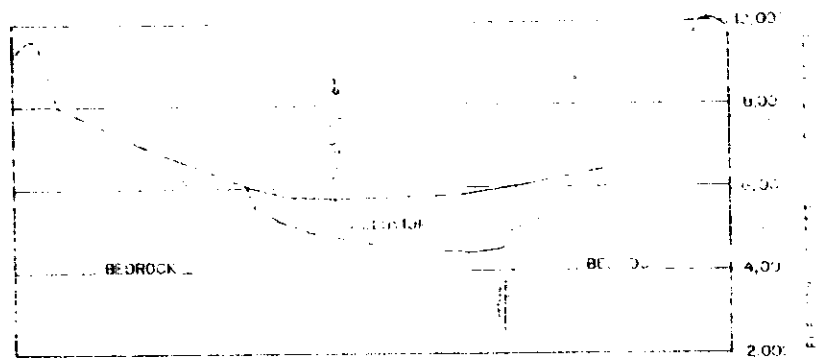
The normal annual precipitation in the drainage basins ranges from a low of 6 inches in the rain shadow of the White Knob Mountains (Big Lost River Valley near Chilly) to over 40 inches for the highest portion of the Lemhi Range (between the Big Lost and Little Lost River Basins). Most of the Pioneer Basin receives 8 to 10 inches, while over half of the area of the mountain basins receives less than 16 inches. The prevailing winds move from west to east; thus, much moisture is removed from the atmosphere by orographic precipitation in the mountains west of the Big Lost River Basin. Normal rainfall is generally higher in the mountains to the west than it is in the Big Lost River Basin[12].

The combined Big Lost River-Pioneer Basins range in elevation from 4,784 feet to over 12,600 feet above sea level. Thus, the area has over 7,000 feet of relief; this results in large differences in temperature or climate at any given time. The low land in the Pioneer Basin has been subjected to periods of warm wind, rain, and snowmelt during the winter months. These periods have caused runoff and minor flooding in the lower basins during regional storms that substantially increased the snowpack in the uplands. The largest documented runoff periods in the lower parts of the basins have occurred in January, February, or March; conversely, the maximum runoff from the highlands is usually in May or June. Frost generally leaves the ground in the Pioneer Basin and the valley floors of the mountain basins in March or April. This prepares the permeable soils and gravels to accept surface water by infiltration before the bulk of the snowpack above starts to melt.



LOST RIVER PROFILE





CROSS SECTION NEAR HOWELL RANCH

CROSS SECTION NEAR LESLIE

FIGURE 2. PROFILE AND SECTIONS OF THE BIG LOST RIVER

2.4 Runoff, Infiltration, and Natural Regulation

2.4.1 General Conditions. On the mountain slopes of the basins, where the greatest precipitation occurs, bedrock is at or near the surface. Surface water generated here runs down the slope and out onto the alluvial fans at the base of the mountains (the alluvium above 6,000 feet elevation, Leslie Section, Figure 2, is an alluvial fan). Most runoff disappears into permeable gravel on the alluvial fans. Some of the water is returned to the main streams through springs but most water leaves the Big Lost River Basin as ground water[13]. Surface water is seldom generated in the Pioneer Basin or on the lower slopes of the Big Lost River Basin. Here the soil's infiltration capacity is much greater than normal rainfall[2,8,12,13].

2.4.2 Big Lost River Basin. The two northeast-trending tributaries of the Big Lost River generally flow through bedrock valleys and undergo minimal surface water losses to ground water underflow until they join the main (northwest-trending) valley. The amount of surface flow generally decreases downstream from where the bedrock valleys join the fault block valley. The rate of loss (infiltration) varies depending upon the volume of water flowing in any flood crest and the condition of the ground which the flood covered. In general, a higher percentage of the flood crest would be lost from larger floods than from smaller floods. The surface area covered by larger floods in the Big Lost River Valley is a geometric function of the flood stage. Infiltration capacity away from the main channel is higher because the ground generally is more permeable. The transient channel storage also increases geometrically with increasing flood stage. The effect of these parameters is to moderate the crest of any flood; the degree of moderation increases with the size of the flood and the distance the flood crest travels.

Thomas[12] discussed flood regulating features in the Snake River Basin. He identified the streams in the local mountain basins (Figure 1) as naturally regulated. The degree of regulation can be seen by comparing the periodic Big Lost River floods in Table I with the geographic locations shown in Figures 1 and 2.

The flood crests increase from Wildhorse to Howell Ranch in proportion to the increase in drainage area. Near Howell Ranch the stream leaves the bedrock valley and flows over deep alluvium. In the reach between Howell Ranch and the inlet to Mackay Reservoir, the drainage area is almost doubled but the flood crests decrease due to natural regulation. From Mackay Reservoir to the NRTS Diversion, the drainage area is nearly tripled, but the calculated flood crests increase only slightly.

2.4.3 Pioneer Basin. The Big Lost River leaves the mountains at Arco. Below this point the topography and drainage characteristics along the river change. The area is a low,

TABLE I

PERIODIC FLOODS IN THE LOST RIVER – PIONEER BASIN

Location	Area Sq. Mi.	Mean Annual Flood cfs	Expected Flood Crest in cfs For Selected Return Periods 2.3 Yr.	20 Yr.	50 Yr.	100 Yr.	300 Yr.
Wildhorse[1]	114	680	680	1,156	1,292	1,496[2]	--
Howell Ranch[1]	448	2,200	2,200	3,740	4,180	4,840[2]	--
Inlet, Mackay Reservoir[1]	776	1,570	1,570	2,826	3,297	3,611[2]	--
NRTS, Flood Diversion Dam[3]	1800(±)	--	--	2,800	3,500	4,100	5,300

[1] After Thomas[12]
[2] Extrapolated from Thomas' Curve
[3] After Carrigan[3]

flat plain with basalt bedrock. The drainage from most of the area in Pioneer Basin is not integrated with the Big Lost River. Locally, some depressions in the basalt receive intermittent runoff. There is seldom enough precipitation in excess of the soils infiltration capacity to push intermittent streams to the Big Lost River.

The Big Lost River flows over a broad, flat flood plain for the first few miles below Arco. Here it enters a shallow, steep-walled canyon carved in the Snake River basalt. The canyon ends at the NRTS Flood Diversion Facilities where the river turns northward onto a second flood plain.

2.5 Recent Flood History

2.5.1 General. The local climate, relief and geology combine to regulate local floods. The individual reasons for natural regulation have been explained in the preceding sections. The total result can best be shown by describing actual flood situations which have occurred in the Big Lost River and Pioneer Basins.

2.5.2 Flooding in February, 1962. In the winter of 1962, extensive flooding occurred through southern Idaho and northern Nevada[14]. Local flooding was confined to Pioneer Basin and the lower valleys of the three local mountain basins (Figure 1). The events leading to the flooding started in late fall and winter when a larger than normal amount of precipitation fell and infiltrated into the soils. Later, a cold period drove the frost line deep into the soil and formed ground ice, effectively eliminating the soil's permeability. Later, snow fell on the frozen ground. Above-freezing weather, accompanied by wind and rain, triggered the flooding. Water from the rain and snowmelt could not infiltrate into the frozen ground; it began moving downslope to the Big Lost River. Minor flooding occurred in most of the areas as the warm weather persisted. The Big Lost River channel was running full; water filled the Big Lost River sinks and started moving down the channel towards TAN. The warm weather was also drawing frost from the ground. When the frost left, the flood virtually sank into the permeable basin soils leaving the last snow drifts to waste away without generating any more surface water.

2.5.3 Flooding in 1965. A record snowpack occurred in the Big Lost River Basin in the winter of 1964-65. The maximum runoff occurred in late June. The Mackay Reservoir was full and most of the runoff was passed on down the basin. The Flood Diversion Facilities on the NRTS were put to their first major test. During the peak of the flood, June 29, 1965, about 1,600 cfs were diverted to the spreading areas from a peak flow of 2,215 cfs[4]. The Big Lost River was out of its banks above Arco through most of the month of June. On the NRTS, the flood was controlled by the Flood Diversion Facilities and the normal infiltration in the river channels, playas and sinks.

The lower valley and Pioneer Basin soils were free of frost for about two months before the peak runoff. The natural permeability augmented by the NRTS Flood Diversion Facilities and the storage in the channel and playa areas consumed the flow. Water did not reach the end of the Big Lost River channel at the Birch Creek playa during this flood.

This flood is significant because it exhibited the largest crest and largest water volume to be discharged on the NRTS in 49 years of record[5], yet it caused no damage to NRTS facilities.

2.5.4 Flooding in 1969. A considerable amount of snow accumulated on the NRTS in December and early January. On January 14, a warming trend began; by January 19, this trend had turned into a "chinook-like" condition with light rain and warm wind. Surface water started moving over the still frozen ground on January 19. Deep drifts blocked some culverts and borrow ditches and caused some water to run over Highway 20, the Central Facilities Area (CFA) rail spur, and some NRTS roads. By January 21, frost was leaving the ground and surface water began sinking into the soil. On January 23, the temperature dropped below freezing and surface water decreased. The saturated upper soil again froze as cold weather drove the frost into the ground; at elevations of 5 to 6,000 feet where snowmelt was incomplete, water and slush froze to leave one to three inches of ice on the ground.

More snow accumulated in February and early March. The spring thaw began in mid-March when temperatures during most of the daylight hours were above-freezing. By March 24, above-freezing temperatures persisted into the night, increasing snowmelt; surface water again started moving at the south end of the NRTS. Water flowed over Highway 20; near CFA, water flowed over East Portland from March 24 to March 28. The flooding at the south end of the NRTS was essentially over on March 28 when the last of the frost left the ground.

The warming trend at the north end of the NRTS had been moderated by cold air drainage from the mountain valleys. Thus, flooding near ICPP was over when heavy runoff began near TAN. March 28 marked the heaviest runoff from the area around TAN. Dikes were constructed to protect temporary LOFT construction buildings and material yards which were built on the playa floor (4,778 to 4,780 feet elevation).

Reconnaissance indicated that most of the water was coming from the lower valley floor of Birch Creek and the alluvial fans along the Lemhi Mountains. Frost and ground ice had essentially negated the normal permeability of the alluvial gravels. Melting at this time was occurring up to about 5,500 feet elevation. Above that elevation, the snow was still frozen and surface water was not evident.

On March 29, emergency construction of channels was begun from the Birch Creek distributaries to a gravel pit about 1½ miles north of the hangar west of TAN. The channels were completed March 30 and Birch Creek was diverted into the pit. By March 31, all snow had melted to about 2 miles northwest of state Highway 22 (elevation 5,200). This was the first day that snow started melting at Blue Dome (elevation 6,100), about 18 miles up the valley from the NRTS boundary.

On April 2, a warm rain occurred in the Birch Creek and Little Lost River valleys. The Little Lost River and Birch Creek were rising a few miles upstream from the Pioneer Basin (Figure 1). On April 3, a set of channels was started from Birch Creek to a second gravel pit near Highway 22 in anticipation of the coming flood crest. At this time, about two-thirds of the Birch Creek water, which passed under Highway 22, was sinking into the alluvium before it reached the gravel pit near the hangar.

On April 4, the writer hiked across still melting snow to the Reno Diversion Dam (three miles north of NRTS at 5,600 feet elevation). High water marks in the Birch Creek channel indicated the creek had crested the day before (April 3). At high water, a channel about 60 feet wide had carried water about five feet deep. This was several times more water than had been observed a few miles downstream at Highway 22 on the NRTS. Subsequent investigations indicated that the frost had left the upper sinks before the flood crested, which explained some of the water loss. Ice jams along the main channel had caused water to spread into subsidiary channels where it was lost by infiltration into the gravels which were then frost-free. Thus, the major crest of the 1969 Birch Creek flood did not reach the NRTS. Natural mechanisms dissipated most of the water before it reached the emergency facilities built to control the anticipated flood.

3. INFORMATION FROM THE GEOLOGIC RECORD

3.1 General Evidence of Paleoclimate Cycles

The alluvial deposits at ICPP range from 35 to 50 feet thick. The soil particle sizes range from clay sizes up to 2- to 3-inch gravels. The bulk of the deposits are sands and gravel which were deposited under flood conditions. Size of particles and the size of individual beds or lenses (lens-shaped deposits, thick in the middle and thin at the edges) indicate larger volumes of flood water and higher energy conditions than would be expected on the basis of historic flood records.

The geologic record indicates that long periods of heavier precipitation have occurred in the past under different climate conditions. Pleistocene time, the last 1.7 million years[15], has been marked by the advance and retreat of several continental ice sheets. The last of these continental ice ages occurred during the Wisconsin glacial age; it started about 70 thousand years before the present (BP) and ended about 10 thousand years BP[16]. Near the end of the Wisconsin period, Lake Bonneville (Utah) reached its highest level, spilled over Red Rock Pass, and caused the Bonneville flood in the Snake River[17]. This was apparently associated with the maximum runoff in Recent geologic time. Since the Bonneville flood, the level of ancient Lake Bonneville has fallen, leaving the Great Salt Lake in Utah as its remnant[18].

The Wisconsin period has been studied in the stratigraphy of the Greenland Ice Cap. Correlation of ice strata, continental pollen and carbon-14 analyses have verified the Wisconsin age dates and have also indicated other short- and long-term climate fluctuations with periods of 400 to 2,400 years[16].

3.2 Climate Cycles in the Snake River Basin

In the region around the Snake River Plain, early Wisconsin valley glaciation is locally called Bull Lake, while late Wisconsin is called Pinedale[19]. Bull Lake started about 70 thousand years BP and lasted until about 25 thousand years BP. Pinedale began about 25 thousand years BP and ended about 7.5 thousand years BP. Both ages are marked by the advance and retreat of valley glaciers. At least one period of valley glaciation occurred before Bull Lake[20].

Archeological excavations at the Wasden Site, a cave in basalt about 17 miles west of Idaho Falls, indicate shorter cycles within the major glacial cycles. The excavations exposed a section of cave sediment that spanned from the present back into Pinedale time. Disruptions in the bedded sediments showed ". . . presence of six well-developed unconformable horizons below which sets of ice wedges had formed. Three of the sets are bracketed by the approximate radiocarbon dates of 6600 and 7900 BP. Two other sets are older, one is younger."[21] The ice wedges caused by permafrost conditions in the cave environment indicate colder and/or wetter than normal climate conditions on the surface outside the cave. Thus, there were three colder and/or wetter climate cycles on the Snake River Plain in about 1,300 years near the end of the late Pinedale glacial stade (episode). One cold cycle has occurred since late Pinedale[22].

In the 1930 decade, Stearns[10] studied trees on the Snake River Plain for paleoclimate information. He found that the age of juniper trees clustered at several points in time. He concluded that these clusters coincided with wetter periods favorable to growth of young junipers. The junipers needed several wet years in succession to establish themselves so they could survive through the dry portion of the climate cycle. The ages clustered in multiples of 200 or 400 years BP. Near Blackfoot, several cedars about 1,600 years old were found growing on basalt flows. Because cedars require more water than junipers, Stearns concluded that the cycle occurring then probably had been longer or wetter than the normal cycles. His work with tree rings indicated that the 1920-1930 decade was the driest in about 300 years.

3.3 Flood History from the Geologic Record

3.3.1 **Walker's Observation.** Walker[23] noted that the quantity of gravel spread by the streams from the mountains indicated a wetter period during which the streams were much larger than they are now. The present streams move very little coarse alluvium. The mantle of wind deposited loess on the gravels indicate that the flood plain away from the stream channels has not been flooded for a long period of time.

3.3.2 **A High-Water Mark on the Flood Plain.** An attempt was made to determine the maximum depth of water that ever flowed over the flood plain near ICPP. A section was surveyed from AEC Butte, near the Test Reactor Area (TRA), across the flood plain at right angles to the flood plain slope. The section passed a few hundred feet northeast of the ICPP fence, continued across the flood plain, and ended on basalt bedrock southeast of the flood plain (see Figure 10, Section 6).

Local geologic conditions lend themselves to determining a high water mark on AEC Butte near ICPP. AEC Butte is an older basalt dome which has been partially buried by Big Lost River alluvium. The soil mantle near the top of the butte consists of windblown loess and weathering products derived from the basalt bedrock. The soil at the base of the butte contains a high percentage of sand and pebbles transported from the mountains by the river; these alluvial fragments can be identified by size, shape and mineral constituents.

Soil samples were taken at various elevations along the profile on AEC Butte. These were seived and separated into particle size fractions. The fractions were examined under a microscope to determine the origin of the particles. The coarser fractions (4, 8, 16-mesh) were assumed to be the diagnostic particle sizes to determine water transportation and deposition; the grains in the finer fractions can be transported upslope by wind. It was assumed that quartz, chert, jasper and rhyolitic fragments in the coarser mesh sizes were indicative of water deposition. The basalt bedrock of AEC Butte does not contain this type material and the particles are too heavy to be moved by normal aeolian (wind) processes. The percentage of diagnostic grains decreased from a few percent near the bottom (elevation 4,915) to a fraction of one percent at elevation 4,925. Above elevation 4,928, all the samples contained a trace of the diagnostic grains (less than 0.1 percent); however, this uniform trace can be attributed to bird droppings, unusually severe wind storms, or other natural processes. The anomaly occurs mainly below elevation 4,925.

On the basis of this study it appears that, for discussion purposes, we can assume the maximum flood in the geologic record came no higher than the 4,925 to 4,928 elevation of AEC Butte. Using the cross-section of the present flood plain and flood plain slope in the Manning slope-area equation[24,25], it appears that it would take a flood crest of several million cubic feet per second (cfs) to reach this stage under present flood plain conditions. A crest this size is not compatible with the other geologic data from Pioneer Basin. This flood would have filled the low portion of Pioneer Basin in a few hours and would surely have pushed through Mud Lake Basin to the Snake River. Geologic evidence does not support this happening. On the other hand, there is ample evidence of sand dune migration across the flood plain. The sand dunes could have dammed flood waters causing local high water indications, a more probable explanation of the apparent high water mark.

The apparent high water mark is of little practical use for estimating the maximum flood; however, it does give some information useful for evaluating the safety of the calcined storage bins in the ICPP area. One can conclude that there is an extremely low probability of flood crests on the flood plain high enough to endanger the calciner bins; this takes into account periods measured in geologic time (thousands of years) and possible geologic hazards.

3.3.3 Old Flood Channels and Natural Levees. A study of aerial photographs, topographic maps and cross-sections made in this study reveals a pattern in the flood channels which gives some indication of past maximum floods. In several places where the channels are well-defined, they are bounded by natural levees (Figure 3). The capacity of the channels at two locations was estimated using the Manning slope-area method[24,25]. Cross-sectional area was determined by survey, while the slope was assumed to approximate the ground slope of the flood plain. The results indicate that the channel sections could carry at least 20 thousand cfs between the natural levees. At flows somewhat over 20 thousand cfs, over-bank flow would probably reinforce the levees with some deposition. At flows approaching 30 thousand cfs, over-bank flow would erode the levees, cut a pass, and change the channel. The silt in the section is easily eroded. Its presence on the levees and on the gravels beyond the levees indicates a considerable period of geologic time has elapsed since a flood exceeded the capacity of the flood channels. This part of the study indicates that maximum floods of at least 20 to 30 thousand cfs have occurred on the flood plain; however, these floods probably occurred in wetter climate cycles discussed in Sections 3.1 and 3.2.

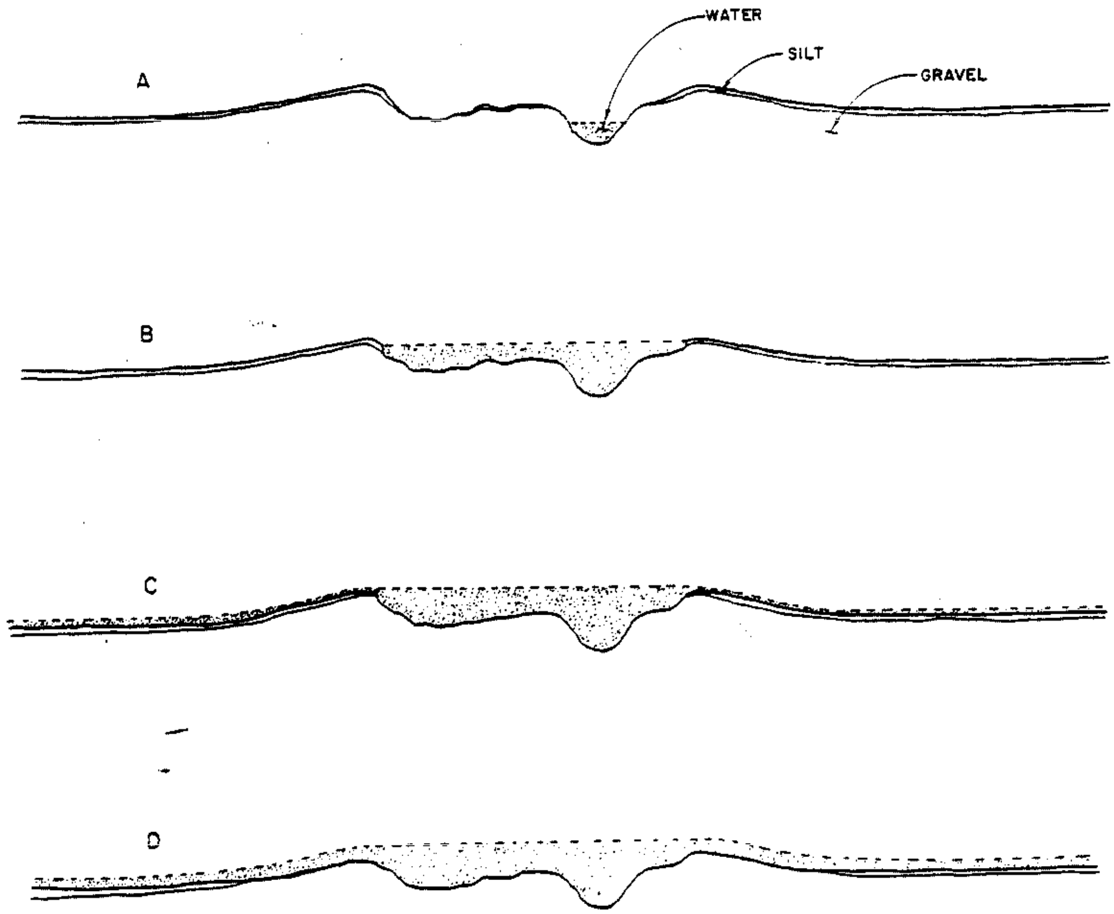


FIGURE 3. FLOOD CHANNELS AND NATURAL LEVEES. The four sketches show different flood conditions in the same channel section. The vertical scale is greatly exaggerated; on the Big Lost River Flood Plain, the vertical relief from channel bottom to levee top would be 6 to 8 feet, while the distance between levees would be one to two thousand feet. Section A shows the existing condition: water flows in a channel incised below the general flood plain surface; windblown silt (loess) mantles the levees, flood plain, and some of the interfluves between flood channels. Section B shows conditions of a flood which is contained within the natural levees. Water spreads from the main channel (Section A) into the flood channels; the velocity is great enough to move sands and gravels in the bed load; the loess has been stripped from the interfluves. Section C shows a flood of about 20 thousand cfs in the section: the velocity down channel is high; however, sand and silt sized particles are deposited on the levees as velocity decreases in the overbank flow. Silt and clay-sized particles are deposited on the flood plain away from the flood channels. Section D shows a large flood where the levees become unstable; overbank flow increases so that sand and silt-sized particles are stripped from the levees. This could lead to concentration of flow and cutting passes through the levee; thus, the levee would be destroyed.

4. FLOOD MITIGATING FEATURES

4.1 Mackay Dam

The holding capacity of Mackay Dam is about 45,910 acre feet: it was built and is operated primarily for irrigation in the Big Lost River valley above Arco[13].

4.2 NRTS Flood Diversion Facilities

The location of the NRTS Flood Diversion Facilities was shown in Figure 1; an aerial photo of the area during the 1965 flood is shown in Figure 4.

The present system can be visualized as two units connected through a lava ridge by the Connecting Channel (Figure 5). The first unit, Area A, is the smallest, it has minimal storage and a low infiltration rate. Here, essentially all the percolation is through silt; sink holes play a very small part in dispersing the water. The second unit consists of Areas B, C, and D; these areas contain most of the storage, most of the infiltration capacity and, due to sink holes, have a higher infiltration rate.

The storage capacity and infiltration rates for the system, plotted against elevation of the water surfaces, is shown in Figures 6 and 7. Water enters Area A first; storage and infiltration for this area are shown by dashed lines. When the water surface reaches 5,038 feet (NRTS elevation), flow starts through the Connecting Channel to Areas B, C, and D. The water level of Area A is controlled by the head required to allow water in Area A to drain out the Connecting Channel. Area A is an open system; water flows in and fills the area to 5,038 feet elevation and then flows out. The area must fill to slightly over 5,047 feet to top Dike 1. Thus, Area A can be protected by assuring that the Connecting Channel can carry away all the water that can be supplied through the Diversion Channel.

The rest of the flood control system is a closed system with regard to surface outflow. If the water that flows through the Connecting Channel cannot be lost by infiltration or evaporation, a failure of Dike 2 and/or 3 will result. If Dike 3 were to fail, some additional off-site lands would be relied upon for infiltration and storage; however, this additional area is still behind Dike 2. There is presently no way for surface water to escape to an outside drainage unless Dike 2 fails. Under present plans, spillways will be installed in FY-75; since the spillway design is not final, the spillways cannot be evaluated at this time.

The solid lines on Figures 6 and 7 indicate the total storage and infiltration of the system with respect to the water level against Dike 2 in Area B. The elevations on the curves

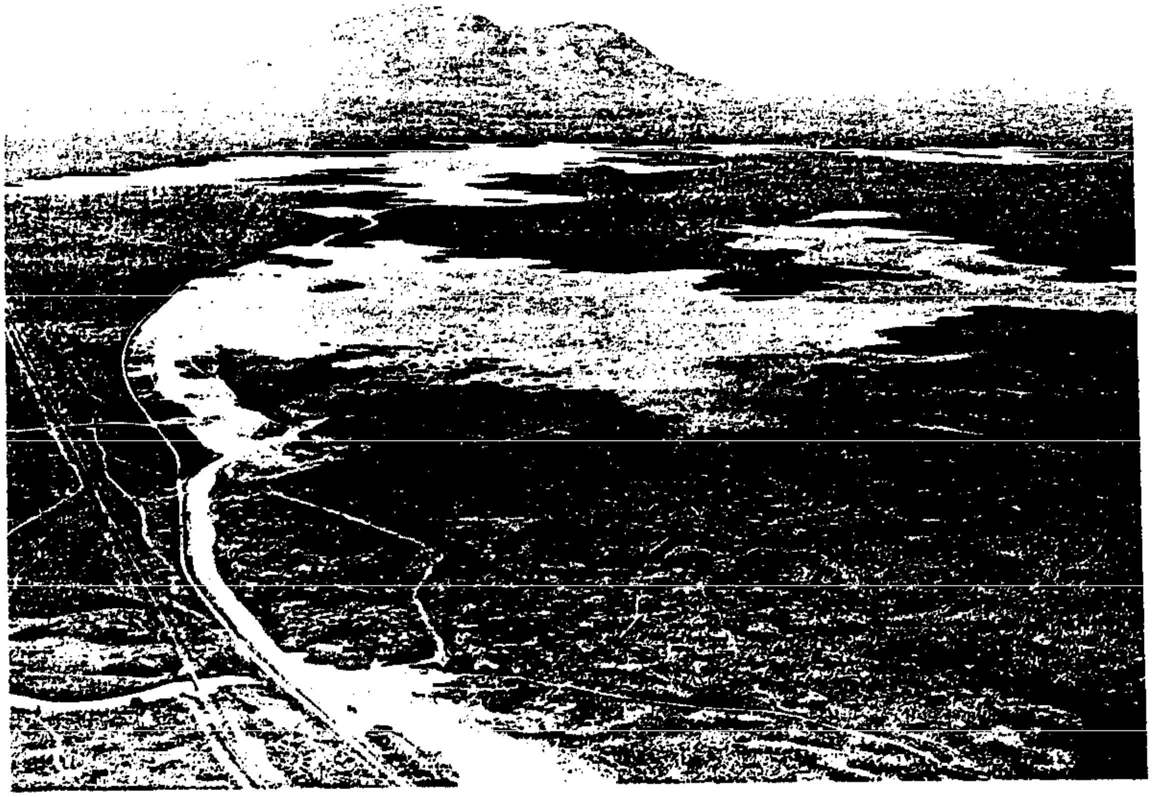


FIGURE 4. NRTS FLOOD DIVERSION FACILITIES DURING A FLOOD. This aerial photograph was taken looking southeast across the spreading areas. The diversion dam is in the lower left center of the photo. The diversion channel leads from the dam to Spreading Area A in the center of the photo. A connecting channel cuts a low basalt ridge to conduct water to Spreading Area B (upper left and center). Water has started through a natural divide and a small amount of water is ponded in Spreading Area C (upper right). No water has entered Spreading Area D. The photo shows conditions the day before the maximum crest of the 1965 flood. Between 11 and 12 thousand acre-feet of water are impounded in the combined spreading areas; this is a small part of the ultimate storage capacity (18,200 acre-feet).

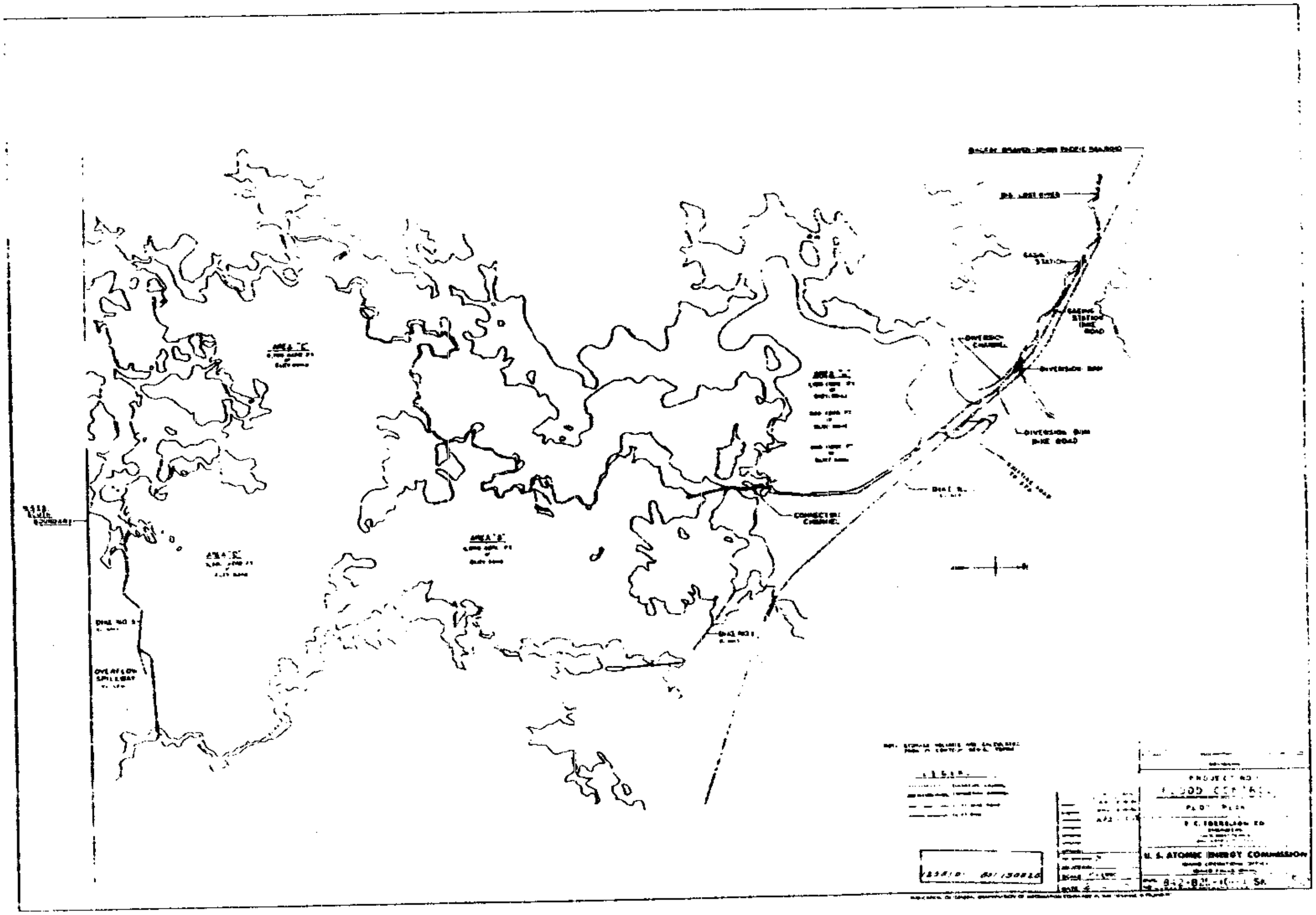


FIGURE 5. PLOT PLAN, NRTS FLOOD DIVERSION FACILITIES. This figure shows one of the original construction drawings outlining the original designed storage. The areas will safely hold much more water now since the area was upgraded in 1966 (see Figures 6 and 7).

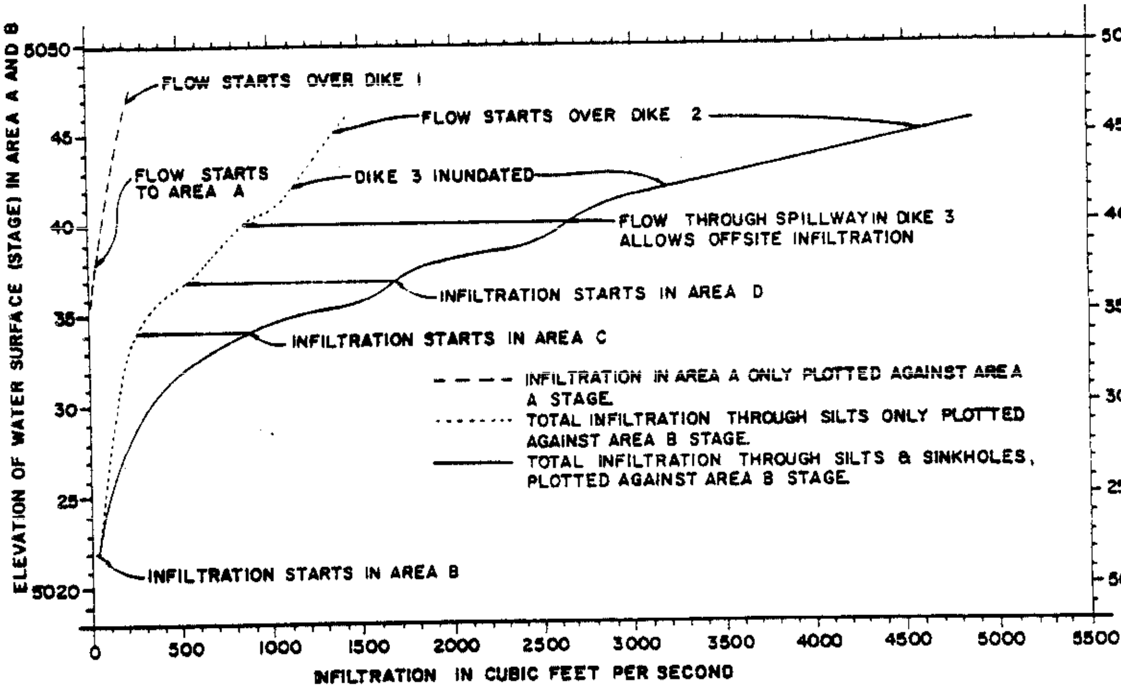


FIGURE 6. INFILTRATION IN THE SPREADING AREAS

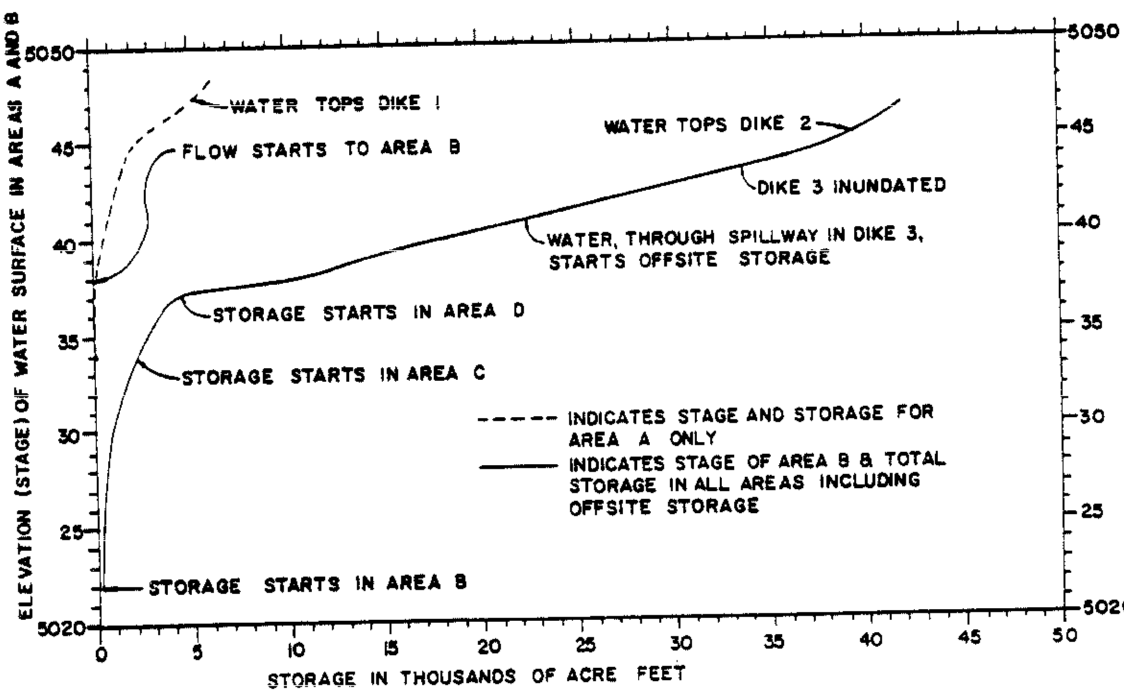


FIGURE 7. STORAGE IN THE SPREADING AREAS

where flow starts to Area C, Area D, over the spillway in Dike 3, and over Dike 3 are indicated. A second dotted line on Figure 6 is included to show percolation through the silt only and indicates possible conditions if the sink holes cease to function at some time in the future (probably hundreds of years away).

The infiltration capacity available in the system is comparable to a 300-year flood crest. Using the best balance of storage and infiltration, flood crests larger than the postulated 300-year flood could be accommodated. Carrigan's study[7] indicated that the channels are now undersized so the storage capacity and infiltration area now available cannot be fully utilized. The dike along the Connecting Channel would fail in a 55-year return period flood.

A proposal to upgrade the channels to accommodate a 300-year flood crest has been made. The work is scheduled for FY-75; when it is accomplished, the only Big Lost River floods that would be of concern to ICPP would be those with return periods greater than 300 years.

4.3 Natural Flood Control

Probably the most important flood-mitigating feature in the drainage basins above ICPP is natural regulation. This was outlined in Part 2.4 and treated by the examples cited in Part 2.5. A fortunate combination of climate, topography, and geology provide the basins with good natural flood regulating characteristics.

5. POSTULATED MAXIMUM FLOODS

5.1 Flood Prediction and Evaluation

Flood evaluation studies are usually made by one of two methods. The water flow and flood crest records can be evaluated statistically and projected into the future to show flood crests and return periods for given time intervals[12]. This method is most frequently used for zoning flood plains, planning water use and evaluating flood hazards. Studies for dam spillways or other critical structures, where a failure could lead to a major disaster with loss of life, use methods based on a maximum storm occurring under the worst conditions. This gives a "maximum" flood for the area in question (USWB Report 43). PMP calculations are used to determine the volume of water that falls as precipitation. The drainage basin is divided into sub-basins; infiltration and runoff is computed to make a flood hydrograph for each sub-basin; and, the discharge shown for each sub-basin is routed into the main basin stream. Flood routing calculations (which consider infiltration, bank storage, channel storage, velocity and distance) are made for the main stream. Thus, the maximum crest can be predicted for points downstream.

5.2 Estimating the Maximum PMP Floods

5.2.1 Predicted Maximum Precipitation (PMP) Method. The PMP storm refers to the maximum precipitation that could occur in an area in a given time span. This is based on the maximum amount of moisture that can be transported into a basin to be released as precipitation by natural atmospheric processes[26]. PMP storms have been considered in this study although flood routing calculations have not been made.

The complex topographical, geological, and climate parameters indicate a meaningful study would, of necessity, have to be quite detailed. For example, the Cedar Creek Basin east of Chilly (in the Big Lost River Basin) has a surface area of less than 10 square miles. The area has about 6,000 feet of relief with the precipitation index ranging from 8 to 50 inches per year (varies by elevation and other factors). The infiltration capacity ranges from none on the upper bedrock slopes to several cu ft/sq ft/day in some of the loose alluvial gravels. Many simplifying assumptions would have to be made to calculate a flood hydrograph for this one basin. By multiplying the possible errors for this basin by the hundred or so other tributary basins in the mountains, the problem of predicting an accurate PMP flood for the Big Lost River Basin can be seen.

In many parts of the United States, PMP storms are a very real threat, particularly in the case of large basins with only one or two thousand feet of relief. In such an area, a PMP storm could cause runoff and flooding over areas that may include several states (Mississippi Basin for example).

Here in the local basins, the same natural parameters which complicate PMP flood routing calculations also act to mitigate the possible consequences of a PMP storm. Under winter conditions, PMP storms would add to the snowpack in the four basins. The most unfavorable fall, winter or spring conditions would be similar to the 1962 floods when storm water runoff was generated on frozen ground in the lower parts of the basins, and added to the snowpack at the upper elevations. During a late spring or summer PMP storm (when melting conditions prevail at all elevations in the basins), natural flood regulation processes would mitigate the flood. The permeable gravels of the alluvial fans would be open, as would the soils in the Pioneer Basin. Thus, a significant portion of the flood water would infiltrate to reduce surface runoff and subsequent flooding in the Pioneer Basin.

In preliminary planning, it appeared that a comprehensive PMP calculation and a PMP flood routing study for the Big Lost River Basin (Figure 1) would take several months and would be expensive. The basin is quite complex, hence anything less than a comprehensive study could give erroneous data and conclusions. The geologic record and

PMP studies in other Idaho basins allows an estimate of the maximum flood to be made. It is believed that this estimate (Section 5.2.3) will be more accurate than a limited PMP flood routing study.

5.2.2 An Estimate of the Maximum (Non-PMP) Big Lost River Flood. Schindler's work (Part 1.2, page 1) indicated the maximum Big Lost River PMP flood crest would be near the low end of a 25 to 78 thousand cfs range. His work was based on a comparative study of other Idaho basins (where PMP flood calculations had been made) scaled to Big Lost River Basin.

The size of old flood channels on the Big Lost River Flood Plain near ICPP (Section 3.3.3, page 13) are in general agreement with Schindler's work. The existing channels and natural levees would probably carry 20 thousand cfs, but would be destroyed or severely altered by floods of 30 thousand cfs.

On the basis of the comparative studies and on geologic evidence, the maximum Big Lost River flood crest at ICPP appears to have been between 20 and 30 thousand cfs. The upper end of this range, 30 thousand cfs, could be considered the maximum Big Lost River flood value in evaluating flood potential at ICPP. On the basis of geologic and paleoclimate data (Sections 3.2 and 3.3), it appears that the last maximum flood happened several thousand years ago in a wetter climate cycle, probably associated with one of the late glacial periods. Thus, a 30 thousand cfs flood could also be considered to be the maximum non-PMP Big Lost River flood which could occur, even with adverse changes in local climate, over periods of hundreds or thousands of years.

5.2.3 An Estimate of the Maximum (PMP) Thunderstorm. PMP calculations were made for a maximum thunderstorm in the Pioneer Basin for various summer months using methods outlined in reference 26, pages 180-186. The maximum storm would occur in the month of August and would cover about 539 square miles. The maximum rainfall (9.2 inches in one hour) would cover about one square mile in the center of the storm. The rainfall would decrease to none at the edge of the storm. An area about 23 by 28 miles would be covered; the general shape of the storm would be ellipsoidal. The pattern of rainfall is shown in Table II. The total rainfall volume from the storm is nearly 90 thousand acre-feet. The average rainfall deposition would be about 3.1 inches over the storm coverage of 539 square miles.

It appears that much more data on permeability, drainage patterns and local storage in many small topographic depressions would have to be developed before meaningful sub-basin hydrographs could be developed; therefore, no sub-basin hydrographs and flood

TABLE II

NRTS THUNDERSTORM RAINFALL DISTRIBUTED IN TIME AND SPACE

Isohyet	Area In Isohyet	Distance From Center	Rainfall in Inches of Rain/Time Period						Total Inches	Cumulative Volume(Acre-Feet)
			1st Hour	2nd Hour	3rd Hour	4th Hour	5th Hour	6th Hour		
A	1 sq mi	1/2 ± mi	.6	9.2	1.7	.9	.5	.4	13.3	709
B	5 sq mi	1/2 - 2 mi	.6	7.0	1.7	.9	.5	.4	11.1	3,668
C	25 sq mi	1 - 3-1/2 mi	.6	5.0	1.7	.9	.5	.4	9.1	12,886
D	34 sq mi	2-1/2 - 5 mi	.6	3.7	1.6	.8	.5	.4	7.6	26,662
E	36 sq mi	3-1/2 - 7-1/2 mi	.5	2.9	1.3	.7	.4	.4	6.2	38,561
F	72 sq mi	5 - 9-1/2 mi	.4	1.9	.9	.6	.3	.3	4.4	55,450
G	78 sq mi	6 - 11-1/2 mi	.4	1.3	.6	.5	.3	.3	3.4	69,588
H	82 sq mi	7 - 13-1/2 mi	.3	.7	.4	.4	.3	.3	2.4	80,080
I	103 sq mi	8-1/2 - 15 mi	.2	.1	.2	.2	.2	.3	1.2	86,669
J	109 sq mi	10 - 17-1/2 mi	0.0	0.0	0.0	0.0	.1	.3	.4	88,933

routing computations were done. The storm was placed at 3 locations in the Pioneer Basin to determine the worst threat to ICPP. The general knowledge of past runoff patterns, coupled with a general knowledge of geology and topography, will allow some discussion and evaluation of potential hazards.

Case 1. Storm Centered over ICPP. When the storm is placed so the maximum rainfall is over ICPP, only about 3/8 of the available rain could drain past ICPP. The rest will follow other local drainages to join the Big Lost River downstream of ICPP. The Monroe-Lincoln Boulevard embankment will channel most of the rain to the Big Lost River. The water volume that could pass ICPP is less than would be liberated by a failure of Dike 2 (see Section 5.4). It appears that the worst effect of a storm located here would be a sheet flood 6 to 8 inches deep. This would result from the rainfall east of Lincoln Boulevard moving to local drainages (as a sheet of water over the surface) and then to the Big Lost River.

Case 2. Storm Centered Upstream of the Big Lost River Flood Diversion Facilities within Pioneer Basin. When the storm is moved to this area, sheet flooding in ICPP is reduced, only about 1 inch of rain will fall at ICPP, thus sheet flooding should be negligible. If the storm is centered in the local drainage basin above Dike 2, the total runoff which could flow into Dike 2 is about equal to the storage capacity of the dike. Spillways, which are projected for construction in FY-75, should accommodate the excess with no difficulty, even if the thundershower should coincide with a long period flood. The safety factors cannot be computed until the spillway design is accomplished. At this time we must assume the spillways will be adequate to handle a PMP thundershower during the same year as the 10,000 year Big Lost River flood. The peak of the 10,000 year Big Lost River flood would occur over a month before the maximum (August) PMP thundershower; as a result, infiltration would lower the water in the storage areas prior to the occurrence of a PMP thundershower.

If the highest rainfall occurred at any other location in the basin above the Flood Diversion Dam, we could expect the Diversion Dam and, perhaps, Dike 1 to fail: however, Dike 2 would remain intact. The runoff should amount to about half the total rainfall when the effect of infiltration and storage in local topographic depressions is considered. As part of the rain would fall outside Pioneer Basin, the volume of water passing ICPP would be about equal to or less than the volume resulting from a failure of Dike 2 (see Section 5.4).

Case 3. Storm Centered Between the Big Lost River Flood Diversion Facilities and ICPP. This condition provides the maximum potential flooding at ICPP due to a PMP thunderstorm. When the isohyets with near maximum rainfall occur over ICPP, a general sheet flooding estimated at between 2 and 3 inches in depth results. This sheet flood would last about an hour before subsiding. Part of the main body of water would flow to the Big Lost River and could be evaluated as a Big Lost River flood. Assuming 90 percent runoff for the 2 hours of greatest rainfall, the projected flood crest would be about 35 thousand cfs. This is larger than a flood from a failure of Dike 2 and would be the largest flood crest expected at the ICPP from any cause.

5.3 Flooding from a Failure of Mackay Dam

The following section is included to estimate the possible effects of a failure of Mackay Reservoir. A value could be obtained by a flood routing study similar to the flood routing for PMP storms; however, in the case of dam failure, much of the water would flow over the flood plain out of the channels. Thus, flood plain sections must be used in the flow calculations. A comprehensive study would require surveyed sections at intervals along the river. In the case at hand, the reservoir capacity is small and natural conditions are favorable for mitigating the effect of a flood.

The capacity of Mackay Reservoir is 45,910 acre-feet[13]. The reservoir is located about 50 miles upstream from ICPP at a restriction in the Big Lost River Valley. Below the reservoir, the valley is quite broad with a flood plain which varies from 1 to 3 miles in width (see Figure 2). The wide flood plain is interrupted by a short basalt canyon on the NRTS below which the flood plain again widens from 2 to 4 miles in width.

A dam failure would lead to the rapid draining of the reservoir; thus, immediately downstream from the Mackay Dam the crest would be high while the flood duration would be short. Below Mackay, the water would spread across the flood plain. The maximum depth would decrease, but the duration of flooding would be longer downstream. Considering the general configuration of the flood plain and the temporary "channel" storage available on the flood plain, the flood at ICPP would probably last more than 24 hours; the maximum crest would be reduced in proportion to the increased time of passage. The average flood crest at ICPP would be on the order of 30 thousand cfs if all the flood water passed by ICPP in a period of 18 to 24 hours. This assumes no reduction by infiltration, since there would be practically no infiltration if the flooding occurred over frozen ground. In reality, the volume of water and the resulting crest would be reduced if the flood occurred in warm weather, because a considerable volume of water would be lost by infiltration. Under any conditions, water would be drawn off by the NRTS Diversion Facilities. The Diversion Dam and part of the Diversion Dam dike road would fail; however, the bedrock diversion channel would carry away a significant part of the flood crest even after a failure of the NRTS Diversion Dam. The Diversion Channel and Connecting Channel capacity would preclude a failure of the dikes.

5.4 Flooding from a Failure of the Flood Diversion Facilities

The NRTS Flood Diversion Facilities (Figure 5) consist of dams, dikes, and spreading areas about 10 miles upstream from the ICPP area. The system is designed to fail safe in a Big Lost River flood. The first failure would be in the diversion channel dike or the Diversion Dam; this would allow the flood to pass downstream without releasing the water stored in the spreading areas.

Water in the spreading areas is impounded behind two dikes. The smaller volume is held behind Dike 1. The bulk of the water is held behind Dike 2 (see Figures 6 and 7). One purpose of the dikes is to route water to existing natural depressions. The level-full capacity of the spreading areas is about 38 thousand acre-feet; however, only about 6 thousand acre-feet would be released by a failure of Dike 1 and about 26 thousand acre-feet by a failure of Dike 2. About 6 thousand acre-feet of water goes into dead storage and cannot drain out of natural depressions.

The dikes are built on undulating terrain where bedrock is usually only a few inches below the surface (see profile, Figure 8). No spillways were put in the dikes due to the limited in-flow and the large storage and infiltration capacity of the spreading areas. However, in FY-75 spillways will be installed. If an unforeseen emergency occurred before the spillways are installed, the dikes would be cut to make an emergency spillway. Dike 1 would be cut between Stations 125 and 130 (see right side, Dike 1 profile, Figure 8); this section of the dike opens to a depression with a rock sill outlet at elevation 5,044. The emergency spillway would save the dike without completely draining the area. Most probably, an emergency spillway for Dike 2 would be constructed between Stations 37 and 40. At that point the dike runs along a narrow rock ridge, and an emergency spillway could be constructed in the rock in a matter of hours.

The NRTS Flood Diversion Facilities present no apparent problems under normal flood conditions; however, if an earthquake occurred in the mountains, a seiche (harmonic water wave in a lake) may top the dike. The chance of a dike failure from being topped by one or two waves is slight; however, the possibility was considered. For analysis purposes, it was assumed the dike would fail at Station 14 where the dike is highest. The break in the dike would eventually become over 900 feet wide; lateral erosion would be mitigated by rising bedrock (the horizontal stations in Figure 8 are spaced 100 feet apart). The crest characteristics at the break were computed using methods of Matthai[27]. The volume of flow is plotted against time from failure in Figure 9. This represents the worst flooding condition from a failure of the Flood Diversion Facilities; other failures were not analyzed.

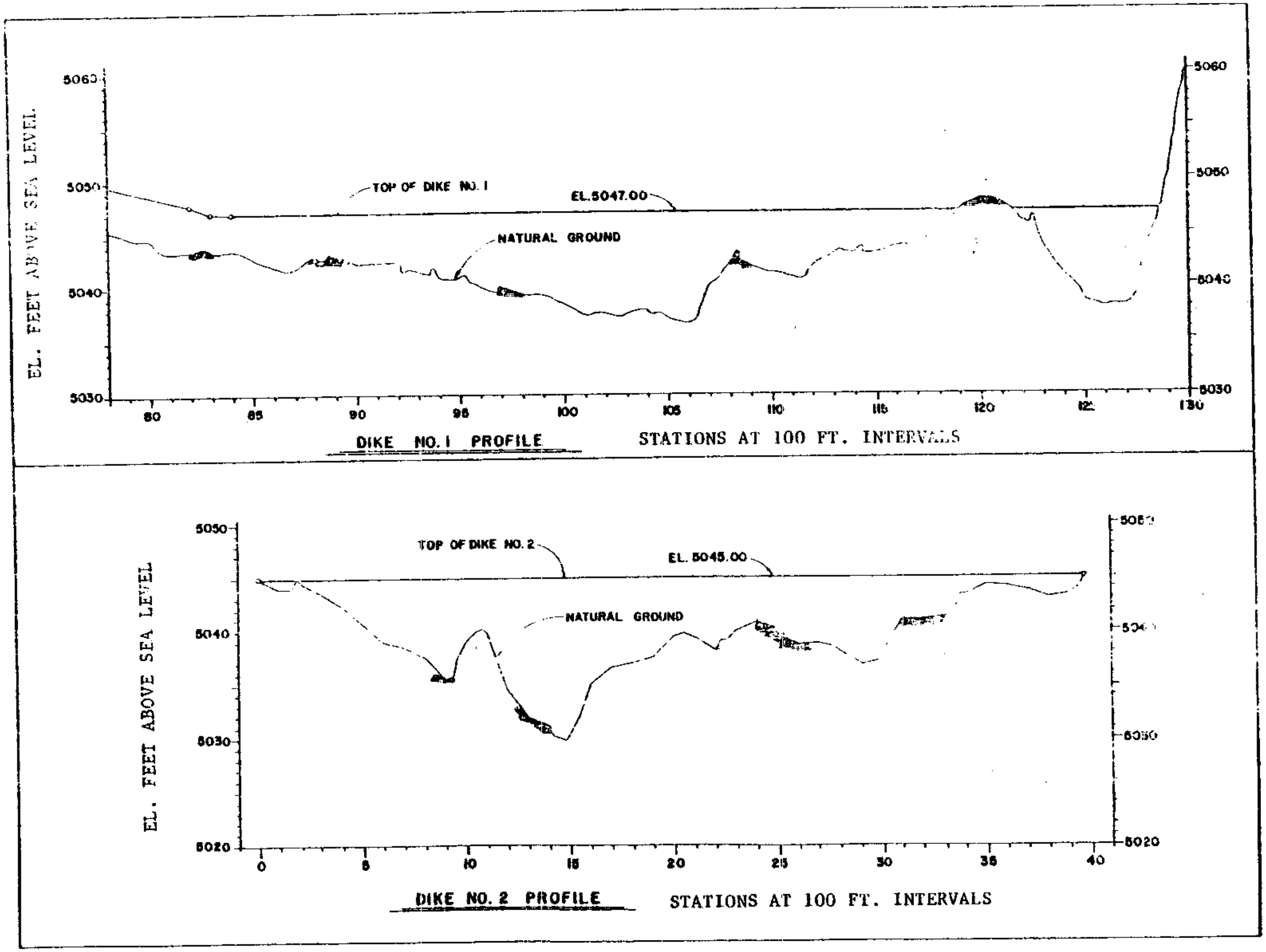


FIGURE 8. PROFILE OF DIKES 1 AND 2, NRTS FLOOD DIVERSION WORKS (72-3712)

Twelve flood plain cross-sections were compiled from topographic maps to estimate the flood routing from Dike 2 to ICPP. Stage discharge computations and channel storage computations were made for the sections to estimate the flood crest at ICPP. The work done with these cross-sections could be considered to be a preliminary iteration; several more iterations would be required to refine the flood crest values, the flood path, and determine the channel storage.

A great deal of water is required to fill the flood plain to dangerous flood levels. It appears that 9 to 12 thousand acre-feet of water would have to be in motion between Dike 2 and ICPP to bring about a 35 cfs flood at ICPP. Because of transient storage in the flood plain, the high instantaneous flood crest immediately below the break in Dike 2 is averaged out by the time flood passes ICPP. The dashed line in Figure 9 is an estimated flood crest at ICPP based on preliminary calculations. The flood would initially travel down a valley between basalt flows. The initial velocity would be high near the dike failure, but the average velocity would decrease to around 5 miles per hour on the flood plain. The flood would reach the flood plain about a mile northwest of EBR-I. Here the flood would spread out as a sheet of water moving north across the flood plain towards the river. The flood would fan out from the Big Lost River bridge on Highway 20 almost to CFA. Lincoln Boulevard, flood ditches, and dikes would tend to move the water to the Big Lost River channel. Lincoln Boulevard (main north-south NRTS highway) and Monroe Boulevard (main TRA access road) would concentrate the water at the Big Lost River bridge near ICPP. Thus, at ICPP the flood would follow the same path as a normal Big Lost River flood. The ICPP stage discharge curve (in the next section) may be used, with the ICPP hydrograph in Figure 9, to evaluate ICPP hazards.

6. FLOOD EFFECTS AT ICPP

6.1 Topography and Works of Man

The area surrounding ICPP is shown in Figure 10. The Big Lost River channel near ICPP was improved in 1959. The channel was straightened and a dike was constructed between the river and ICPP. In the fall of 1962, interceptor ditches were constructed west of Lincoln and south of the Big Lost River to collect local surface water from snowmelt on frozen ground. Monroe and Lincoln Boulevards both slope to their intersection near the Big Lost River bridge (Figure 11, Monroe-Lincoln cross-section). The effect of these road embankments and the interceptor ditches is to concentrate all surface water at the bridge. The road embankments, dikes, and channel improvements are designed to force most of the water north of the channel if the Big Lost River leaves the improved channel.

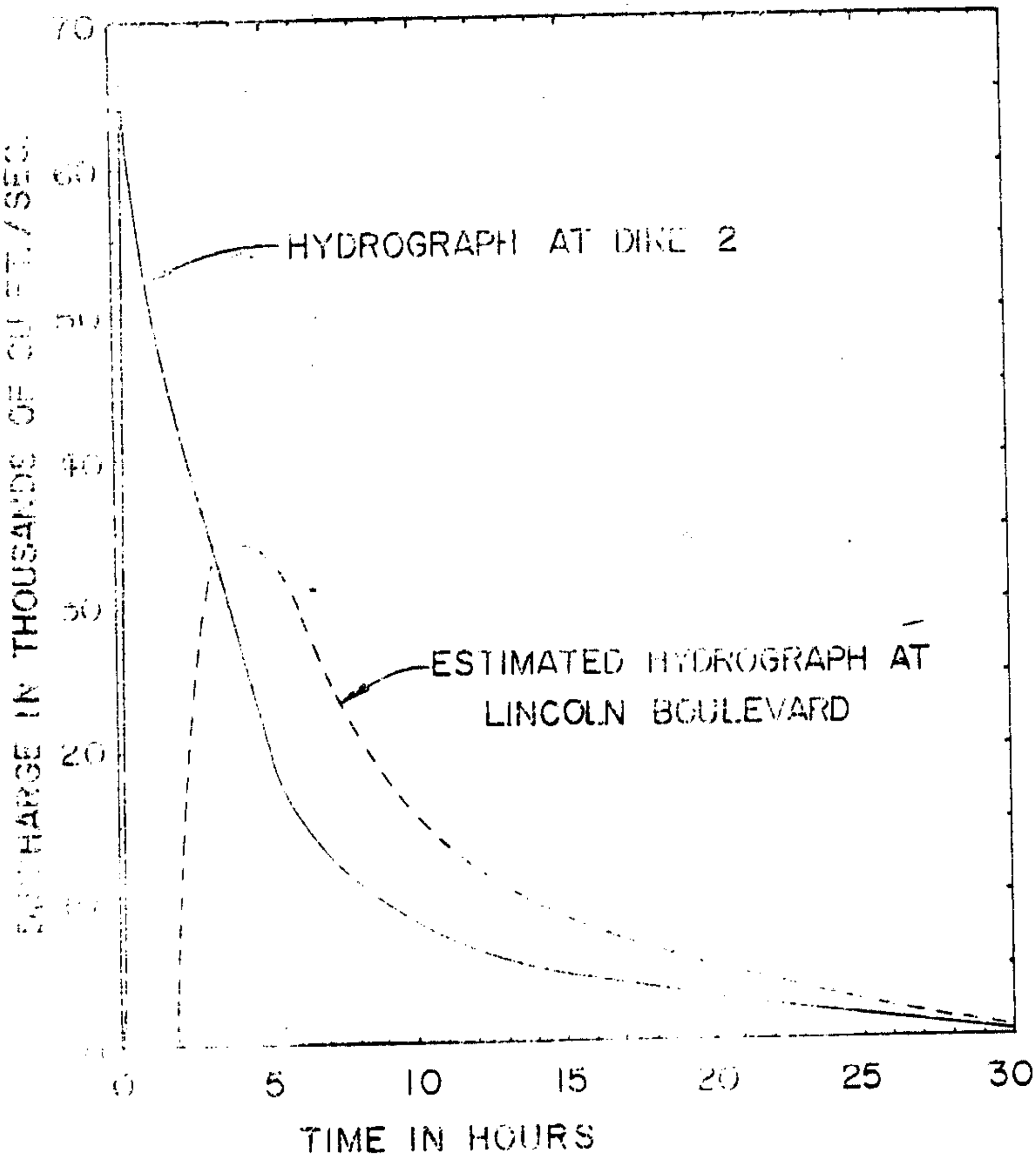


FIGURE 9

[illegible] HYDROGRAPH FOR FLOODING DUE TO THE WORST FAILURE OF DIKE 2

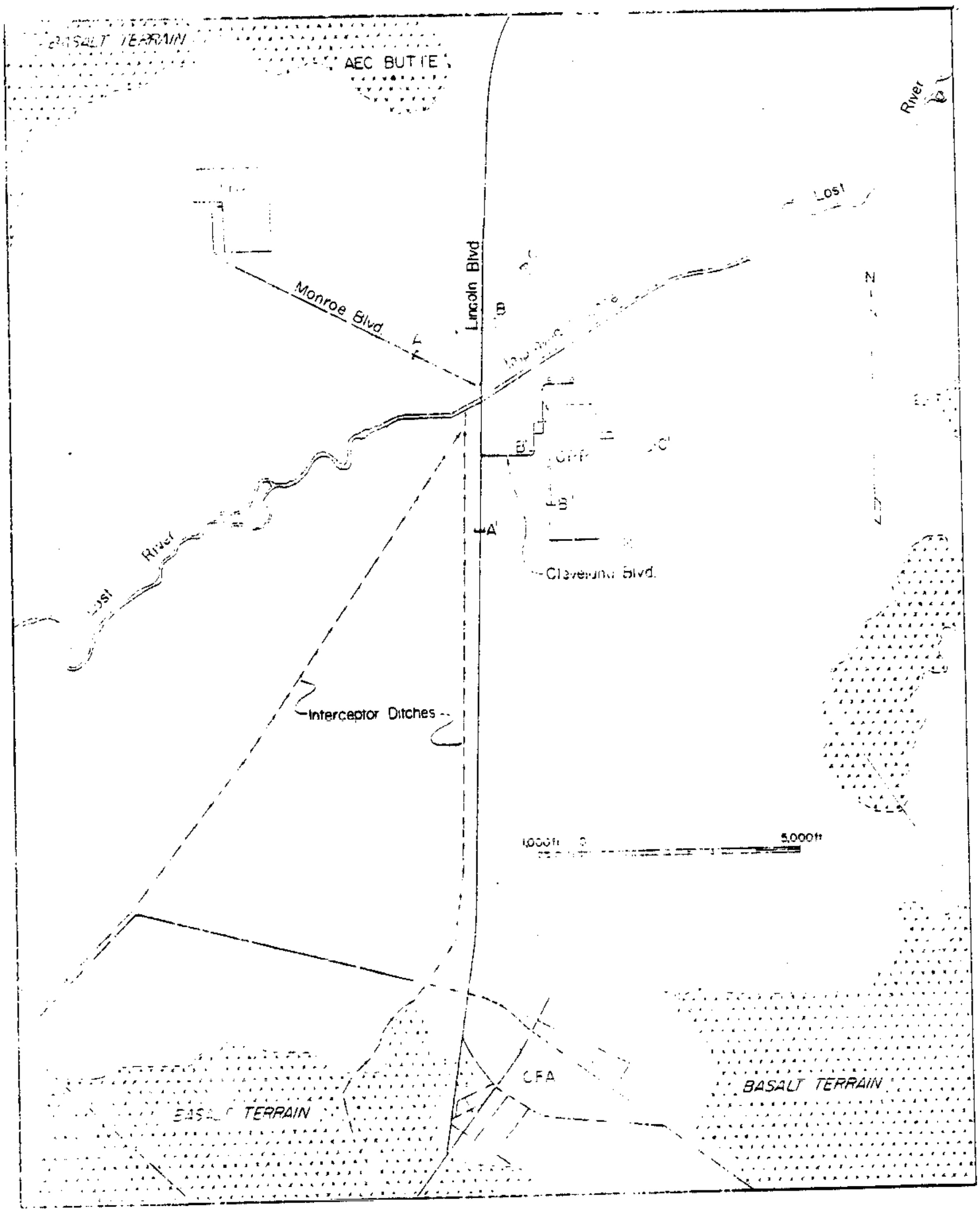


FIGURE 10. MAP OF THE FLOOD PLAIN NEAR ICPP

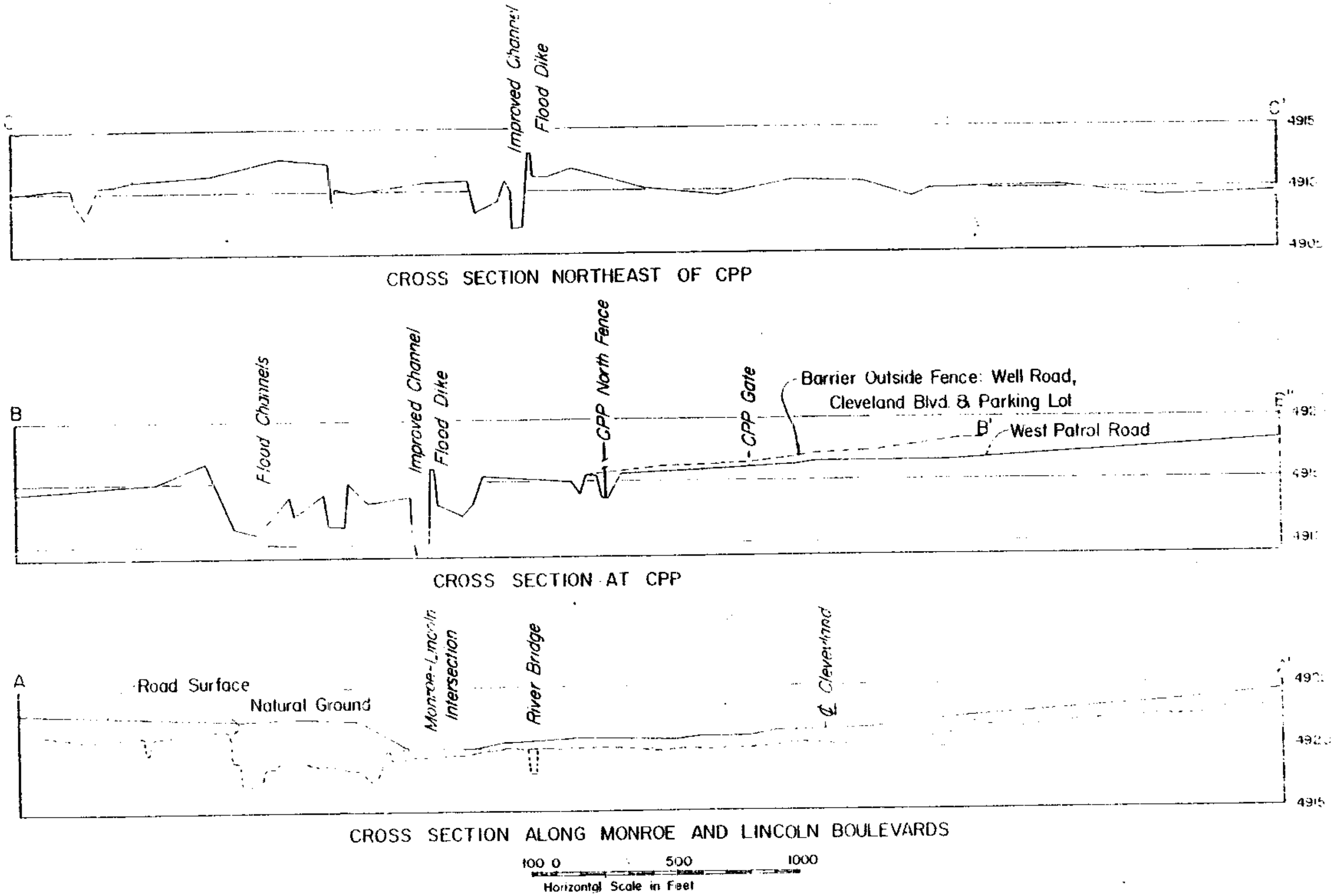


FIGURE 11. FLOOD PLAIN CROSS SECTIONS NEAR ICPP

The NRTS Flood Diversion Facilities (see Section 4.2) presently will protect ICPP from floods up to a 55-year return period (about 3,700 cfs). In FY-75, the facilities will be upgraded to give protection from a 300-year (5,400 cfs) flood crest. In larger floods the Diversion Dam will fail and the flood will be routed down the river channel. Only a small amount of water is stored behind the Diversion Dam so a failure will not greatly increase the flood crest; however, it will allow the full flood to pass by ICPP.

6.2 Stage-Discharge Relationships for ICPP

6.2.1 Monroe-Lincoln Cross-Section. A stage-discharge curve was computed for the Monroe-Lincoln highway embankment using the methods of Hulsing[28]. This curve is shown graphically on Figure 12. "Stage" refers to the water surface elevation, while "discharge" represents the quantity of water in cfs moving past the reference point. The curve may be used with the sections in Figure 11 and the map in Figure 10 to predict water flow at various flood stages. The elevation of the Cleveland-Lincoln intersection is 4,921.6 feet; the discharge at that stage is 5,000 cfs. Thus, for floods less than 5,000 cfs, Cleveland Boulevard will act as a dike to protect the ICPP area. For floods over 5,000 cfs, some water will pass over Lincoln south of Cleveland and will find its way through the ICPP area. The curve (Figure 12) indicates that about a foot of water would flow over Lincoln Boulevard south of Cleveland Boulevard in a 30 thousand cfs flood. Section A-A (Figure 11) shows that Lincoln slopes up to the south so that only a small part of the maximum flood water would pass through the ICPP area.

6.2.2 Stage-Discharge Curve for ICPP. A stage-discharge curve (Figure 13) was computed from a section surveyed at ICPP (Section B-B', Figures 10 and 11). The values were computed by the slope-area method using the Manning equation. The water surface slope was assumed equal to the ground slope perpendicular to the section.

This curve gives the approximate stage-discharge relationship along the west ICPP fence. The depth of water at the west patrol road can be projected east across ICPP to evaluate flood hazards inside the area. Since the ground slopes from southwest to northeast, the flowing water surface will also slope in that direction. Projecting the water depth from the west fence gives a correction to evaluate the flood hazard. The curve indicates that it would take more than an 80 thousand cfs flood to bring the flood crest to the door of CPP-603 in the south end of the area. Water would be somewhat over a foot deep at the CPP-601/602 building complex at that time. However, the maximum flood predicted by this study would be only about 35 thousand cfs. During the maximum predicted flood, water would be only a foot deep at the CPP-601/602 building complex. The building construction is amenable to sandbagging to protect against a 35 thousand cfs flood (even an 80 thousand cfs flood). The water velocity around the buildings would be on the order of 3 to 6 miles

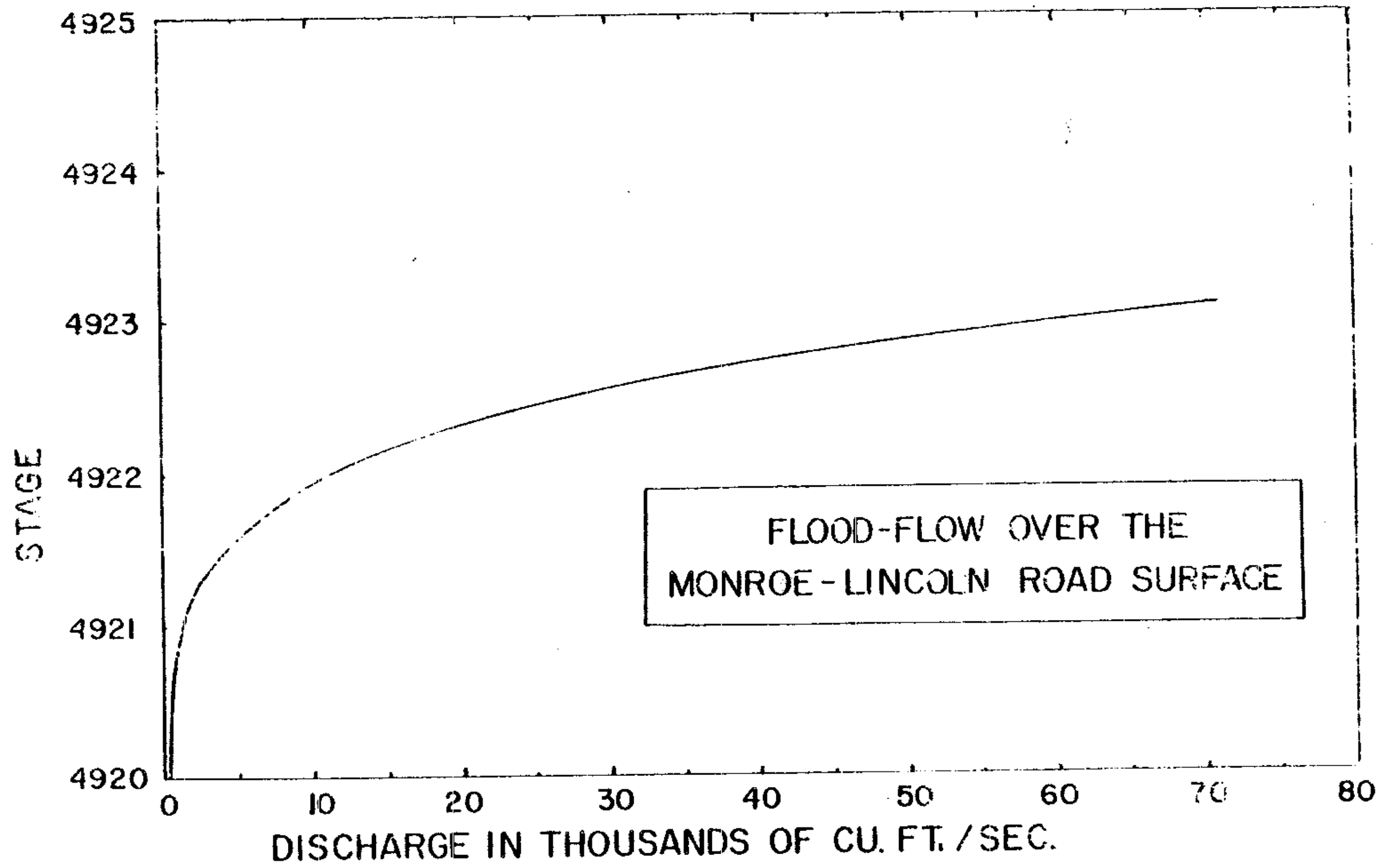


FIGURE 12. STAGE-DISCHARGE CURVE FOR THE MONROE-LINCOLN BOULEVARD BARRIER UPSTREAM FROM ICPP. The curve shows the quantity of water which would pass over the highway for various water surface elevations.

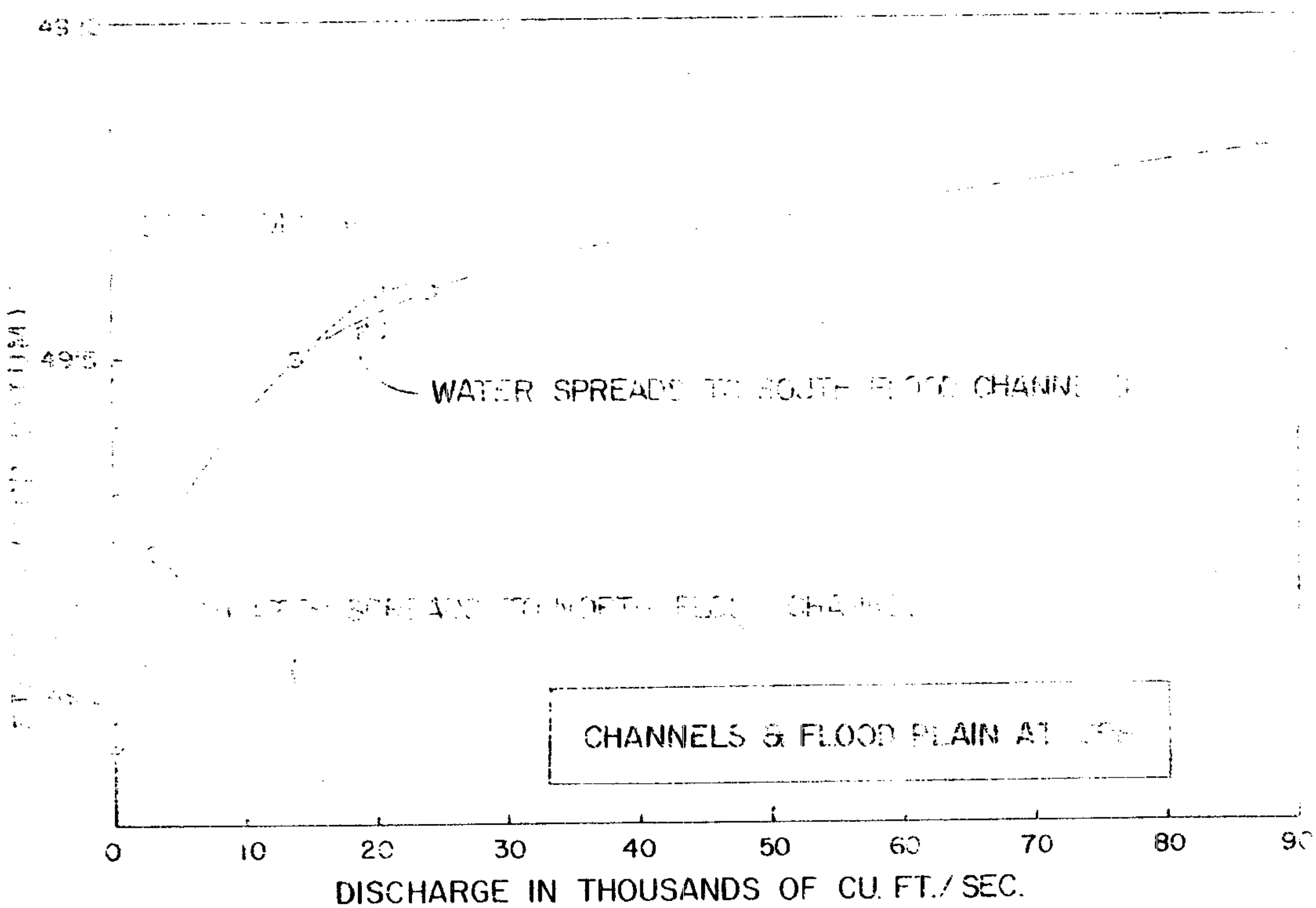


FIGURE 13. STAGE-DISCHARGE CURVE FOR THE LOST RIVER AT ICPP

per hour. This velocity would not be sufficient to cause serious erosion damage to roads, backfill around the buildings or sandbag dams. The shallow water would preclude damage by floating objects (trees, timber, etc.).

The configuration of roads and buildings in the north end of the ICPP area complicates predicting water depth at specific places. During possible floods over 5,000 cfs, some water will flow over Lincoln north of Cleveland. The flow over Lincoln is not accounted for in the ICPP section. For floods of up to 10 thousand cfs, this water should be held west of Birch Street. For floods over 10 thousand cfs, this water may find its way to any place in ICPP north of the Peach Bottom Fuel Element Storage Facility. For evaluation purposes, this could be considered to constitute a "sheet" flood 2 to 6 inches deep over the inundated area.

6.3 Evaluating Flood Hazards at ICPP

6.3.1 General Statement. The preceding paragraphs of this section have discussed four possible maximum flood situations at ICPP. These were:

1. Maximum probable flood in the Big Lost River—30 thousand cfs flood crest.

2. Maximum PMP thunderstorm—35 thousand cfs flood crest.

3. Failure of Mackay Dam with an estimated flood crest of 20 to 30 thousand cfs.

4. Failure of Dike 2 of the NRTS Flood Diversion Facilities with an estimated flood crest between 30 and 35 thousand cfs.

These represent the maximum probable floods that could occur at the ICPP area. The period of time between floods of this magnitude is great (thousands of years) when compared to the foreseeable life of ICPP programs (decades). Examination of the data indicates that most of the essential facilities in ICPP could be considered safe from 300-year floods and are reasonably safe from the maximum probable floods. The following paragraphs will develop means of evaluating the probable floods which can be expected in the life of ICPP programs.

6.3.2 Flood Return Periods. The primary objective of frequency analysis is to determine the recurrence interval of floods of a given magnitude. The average interval of time within which the magnitude of a given event will be equaled or exceeded is known as the recurrence interval, return period or frequency.

It was estimated that the maximum probable non PMP Big Lost River flood would be about 30 thousand cfs. It appears that the last flood of this magnitude occurred about 12 thousand years ago during a wet climate cycle (Section 3.1). On this basis, the return period of a flood of this magnitude would be at least 12 thousand years; however, the Task Committee on the Reevaluation of the Adequacy of Spillways of Existing Dams (American Society of Civil Engineers) recommends using 10 thousand years as the return period (frequency) of maximum probable floods[29]. Thus, 10 thousand years should be considered the average return period for 30,000 cfs Big Lost River floods; this return period would also apply to the PMP thunderstorm flood.

Carrigan[7] computed the flood crest and return periods of Big Lost River floods up to 5.4 thousand cfs which had a return period of 300 years; his work is shown as the solid line on the flood frequency graph (Figure 14). The maximum probable non-PMP Big Lost River flood, 30 thousand cfs, is also plotted on the graph with a return period of 10 thousand years. The frequency and crest of floods between these two points can be interpolated by the dashed line connecting Carrigan's curve with the maximum probable flood.

6.3.3 Flood Probability and Risk Analysis. The probability of a flood of a given magnitude occurring in any given year is an inverse function of its frequency. This relationship is shown by the equation

$$P = \frac{1}{T} \tag{1}$$

where P is the probability and T is the return period[30]. Thus, the probability of a 5,400 cfs flood occurring (Figure 14) in any given year is:

$$P = \frac{1}{300} \text{ or } .0033$$

Most structures at ICPP are designed to be used for production or storage for many years. The simple one year probability must be modified to assess the flood risk over the design life of the structure. The probability of a flood of a given period occurring in the design life of a particular structure is given by the formula:

$$P' = 1 - p^N$$

where p is equal to the probability of a flood *not* occurring in a given year (p = 1-P) and N is the design or expected life of a structure[31].

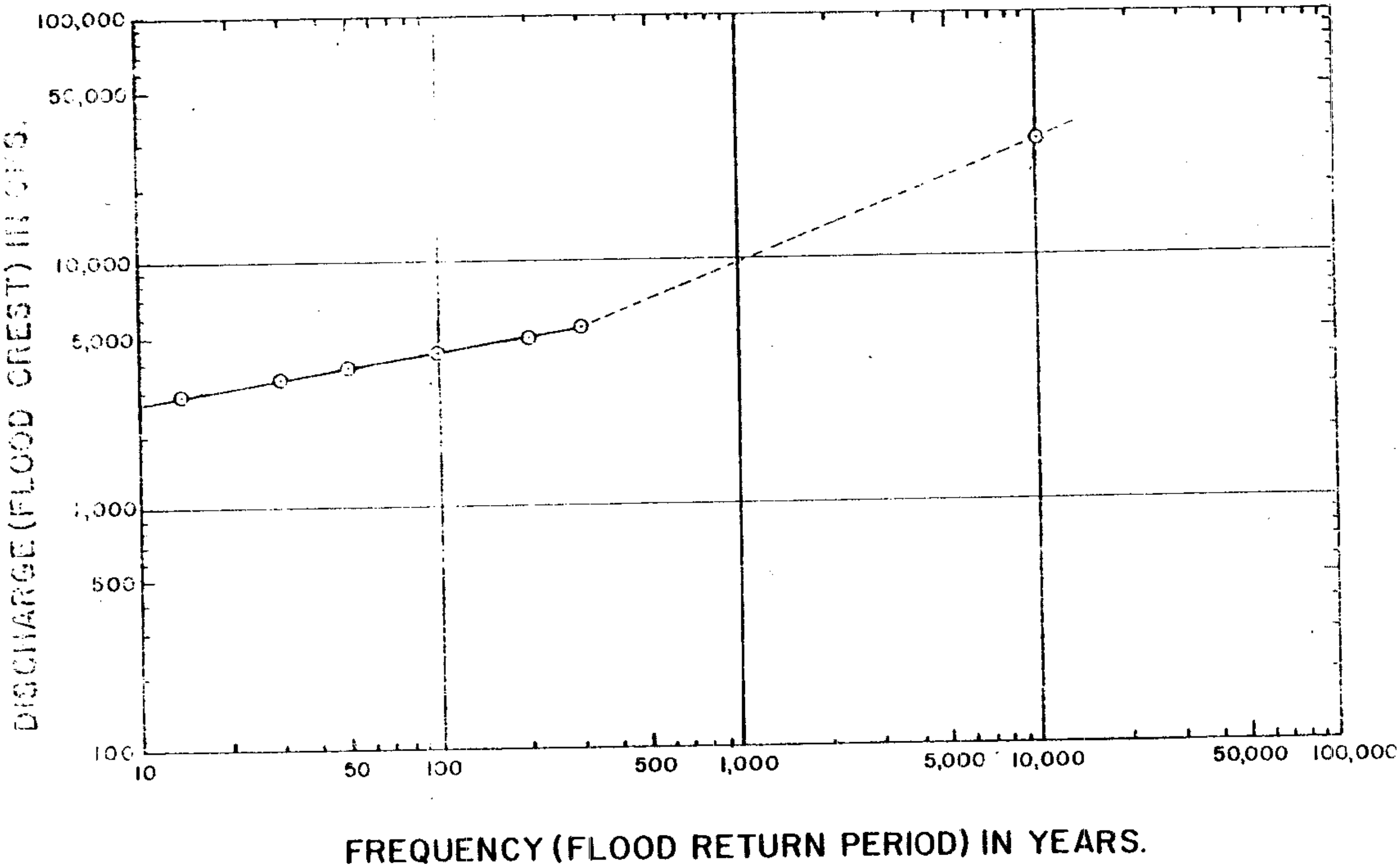


FIGURE 14. FLOOD FREQUENCY ON THE NRTS

For example, consider a hypothetical shed to be used 10 years on the flood plain near ICPP. Assume it would be damaged by a 5,400 cfs flood. The return period of this flood is 300 years (Figure 14); therefore, the probability of damage in any one year (P) is 1/300 or .0033. The probability of its not being damaged in any one year (p) is: 1 - .0033 = .9967, while the probability of its being damaged in its 10 year design life is:

$$P' = 1 - .9967^{10} \text{ or } .0326$$

The structures at ICPP may be analyzed by determining the depth of water outside a structure which would cause damage or a radiation incident. This depth can be projected to the west fence to find the water surface elevation (stage) at that point (Figure 11, Section B-B"). The stage at the west fence can be converted into a flood discharge by using Figure 13. The frequency of discharge is found on Figure 14, so that the yearly or design life risks can be computed as shown above.

The risks and the costs of reducing the risks can then be balanced by trial calculations to determine if the risks are acceptable or if funds should be provided to improve the safety of the facilities[29].

7. SUMMARY AND CONCLUSIONS

A study by Schindler compared the maximum floods from Idaho basins where Predicted Maximum Precipitation (PMP) calculations had been made with the Big Lost River Basin to establish a range of 25 to 78 thousand cfs for the maximum Big Lost River flood. On the basis of basin shape, Schindler suggested that the maximum flood would be near the low end of that range.

The Big Lost River is a naturally regulated stream with natural flood control features. Old flood channels on the plain near ICPP have the capacity to carry about 20 thousand cfs, but would be destroyed or altered by flows of 30 thousand cfs. Thus, it appears that maximum floods in the past have been between 20 and 30 thousand cfs. On the basis of geologic evidence, supported by Schindler's comparative study, the maximum natural (non-PMP) Big Lost River flood crest at ICPP is assumed to be 30 thousand cfs. Paleoclimate data and current flood evaluation practices were used to establish a frequency of about 10 thousand years for this maximum flood.

The possibility of computing the maximum Big Lost River flood by hydrometeorological and flood routing methods was examined. The Big Lost River Basin is very complex; therefore, a study would have to be quite detailed to be meaningful. The hydrometeorological and flood routing studies would give flood values which would have a higher confidence level than the value established in this study; however, it is doubtful if the values would be changed significantly.

Flash flooding from a PMP thundershower was evaluated for storms occurring at three different locations in the Pioneer Basin. The worst condition occurred with the PMP thundershower located between ICPP and the NRTS Flood Diversion Facilities. This storm would produce 2- to 3-inch sheet flooding in the ICPP area and a 2-hour flood crest in the Big Lost River of about 35 thousand cfs. This case provided the worst flooding condition discovered in the study and, therefore, defines the design basis flood for ICPP. The crest would be about equal to a flood from a failure of Dike 2; however, there would be essentially no warning for the flash flood.

Stage-discharge curves were constructed for the flood plain at ICPP. The maximum flood would put about a foot of water in the north end of the ICPP area. Due to the broad, flat flood plain, a flood twice as large would only increase the water level at ICPP by about a foot. If flood protection were designed for a 35-thousand cfs Big Lost River flood, the normal free-board would control a flood more than twice as large.

Man-made structures upstream from ICPP were examined for possible flood threats to ICPP. A failure of Mackay Dam would result in a flood somewhat smaller than the estimated maximum Big Lost River flood. A failure of Dike 2, NRTS Flood Diversion Facility, would result in a flood about 5 thousand cfs larger than the estimated maximum natural Big Lost River flood; this would be about equal to the worst postulated PMP thunderstorm flood of 35 thousand cfs.

A 35 thousand cfs flood at ICPP would not cause serious flooding. The ICPP standard datum, i.e., the elevation of grade level at CPP-601-602 and CPP-633, is at 4,917 feet above mean sea level. The design basis flood would result in flood water within the ICPP controlled area up to 4,916.6 feet MSL.

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